University of Technology, Sydney

Assessment of Pre-treatment to Seawater Reverse Osmosis

By

Khorshed Jahan Chinu

A thesis submitted to fulfilment
of the requirements for the degree of
Master of Engineering

University of Technology, Sydney
Faculty of Engineering

January, 2009

CERTIFICATE OF AUTHORSHIP

I certify that the work in this thesis has not previously been submitted for any degree nor has it been submitted as part of requirements for a degree except as fully acknowledge within the text.

I also certify that the thesis has been written by me. And help that I have received in my research work and the preparation of the thesis itself has been acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

Signature of Candidature

Khorshed Jahan Chinu

(Khorshed Jahan Chinu)

Sydney, January 2009

ACKNOWLEDGEMENT

I express my deep sense of gratitude towards my Supervisor Professor Vigneswaran for his excellent motivation and guidance of my study. I would like to express my gratitude to my principle supervisor, Professor S. Vigneswaran and my co-supervisor, Dr H.K. Shon, for providing me with the opportunity to work in the research project of the pretreatment to seawater, for their valuable guidance and support at all levels during my study at UTS. I would also like to thank Dr Kandasamy for proofreading the thesis and offering constructive comments.

I extend my gratitude to Professor Vigneswaran, who guided me continuously from start to end of my study. I would like to thank him for his financial support during my study. I would also like to thank my co-supervisor, Dr. Hokyong Shon, who offered generous assistance on the start-up as well as the progress of the study. Also, I wish to acknowledge Dr. Hokyong Shon for his financial support during the study. I would like to also thank Dr Hao for his support while working in the Environmental lab.
In addition, I would like to thank Professor Tally Palmer from the Institute Water for Environment and Resource Management (IWERM) for her encouragement and financial support of the study. My special thanks for Johir for his helping hands which lead to successful completion of this difficult task. My appreciation also goes to Laszlo, Javeed, Ben, Rupak, Wen Xing, Dang and Yoshuf for their generous help in the experimental phase of this research, and staff in the Research Office for their friendship and companionship. My appreciation also goes to all the people in SIMS (Sydney marine institute, Chowder Bay, Sydney) for their support to do experiments on-site.

I greatly acknowledge the financial support for the final semester of my Masters degree by Faculty of Engineering, University of Technology, Sydney (UTS).

Finally, I wish to thank my Mother, sisters and brothers for their love and support. Especially my sister Ishrat, without her encouragement and support, it was not possible to come and study in Australia. I am also grateful to my husband for his support.

TABLE OF CONTENTS

Chapter 2

Literature Review 2-1

Chapter 3

Experimental Investigation 3-1

Chapter 4

Results and Discussion 4-1

Nomenclature

A	=	the membrane surface area (m^2)
ASTM	=	American Society for Testing and Materials
BOD	=	Biological oxygen demand
BTSE	=	Biologically treated sewage effluent
BOM	=	biodegradable organic matter
C_b	=	the concentration of particles in a feed water (mg/l)
COD	=	Chemical oxygen demand
CFS-MFI	=	cross-flow sampler modified fouling index
Da	=	Dalton
DOC	=	dissolved organic carbon
DMF	=	dual media filter
EfOM	=	effluent organic matter
HPSEC	=	High pressure size exclusion chromatography
MFI	=	modified fouling index
MWD	=	molecular weight distribution
MF	=	microfiltration
MFI-UF	=	modified fouling index by using ultra filter membrane
MFI-NF	=	modified fouling index by using nano filter membrane
MWCO	=	molecular weight cut-off
NF	=	nanofiltration
NOM	=	Natural Organic Matter
PAC	=	Powdered activated carbon
R_m	=	membrane resistance
RO	=	reverse osmosis
SEC	=	size exclusion chromatography
SWOM	=	Seawater organic matter
Spb	=	pore blocking slope by critical time – pore blocking index (1/L)
t	=	filtration time (s)

TDS	=	total dissolved solid
V	=	total permeate volume (l)
ΔP	=	applied trans-membrane pressure (Pa)
η	=	water viscosity at $20^{o}C$ (N s/m^2)
α	=	the specific resistance of the cake deposited

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

Membrane based desalination is widely used process to produce fresh water either from wastewater or seawater. However, membrane fouling on the reverse osmosis is a major hurdle. It increases the energy consumption as well as operating cost of reverse osmosis. A pre-treatment before reverse osmosis (RO) desalination can significantly reduce the membrane fouling.

The main objective of this study was to assess the relative merits of different pre-treatment processes in terms of membrane fouling reduction, and removal of organic matter in terms of molecular weight distribution and dissolved organic carbon (DOC). Different fouling indices (such as silt density index (SDI), modified fouling index (MFI) and cross-flow sampler modified fouling index (CFS-MFI)) were used to study the pre-treatment efficiency of different process such as flocculation, adsorption, microfiltration and biofiltration.

The effectiveness of different pretreatment on the fouling propensity of the feed was studied using synthetic waste water. The fouling potential of the feed was characterized by standard modified fouling index (MFI) and cross-flow sampler modified fouling index (CFS-MFI). In CFS-MFI, a cross-flow sampler was used to simulate the condition of a cross-flow filtration. The results indicated that the pretreatment such as flocculation with an optimum dose of 68 mg/l $FeCl_3$ and adsorption with powdered activated carbon (PAC) of 1 g/l substantially reduced the fouling propensity of the feed. The standard MFI of flocculated wastewater was reduced by around 99% compared to that of the untreated wastewater. The effect of molecular weight distribution (MWD) of the foulants in the wastewater on the fouling propensity of the feed was also investigated. The MWD of pretreated effluent was correlated well with the MFI and CFS-MFI indices.

Different processes such as flocculation with ferric chloride ($FeCl_3$) and deep bed filtration (sand filtration and dual media filtration) as a pre-treatment to microfiltration (MF) were used for seawater desalination. The performance of these pre-treatments was determined in terms of silt density index (SDI) and modified fouling index (MFI) and flux decline in MF. Flux decline of MF with seawater was 45% without any pre-treatment, 42% after pre-

treatment of $FeCl_3$ flocculation, 24% after pre-treatment of sand filtration with in-line coagulation and 22% after pre-treatment of dual media filtration (sand and anthracite), respectively. MFI and SDI also indicated that deep bed filtration with in-line flocculation was better pre-treatment than flocculation alone. Detailed molecular weight distribution (MWD) of seawater organic matter was examined after different pretreatments. MWD of the initial seawater mainly ranged from 1510 Da to 130 Da. Deep bed filtration with in-line flocculation removed relatively large molecular weight of organic matter (1510 – 1180 Da), while the small molecular weights (less than 530 Da) were not removed.

The removal of particulate matter and dissolved organic matter from seawater by the use of biofiltration was investigated through long term on-site operation of biofilters. Granular activated carbon (GAC) and anthracite were used as biofilter media at two different filtration velocities. Filtrate quality was measured in terms of silt density index (SDI), modified fouling index (MFI) and turbidity removal. Reverse osmosis (RO) was used as a post treatment. Both biofilters demonstrated similar fouling reduction behavior in terms of SDI and MFI. Fouling potential in terms of MFI values decreased to 10 s/L^2 within the first 10-15 days of operation and kept constant up to the remaining experimental period of 55 days of operation for both GAC and anthracite biofilter. The filtrate turbidity was steady after 10 days and remained low at a value of 0.2-0.3 NTU and 0.28-0.31 NTU for anthracite and GAC biofilter respectively. Furthermore, the headloss development was low and within 20 cm for biofilter operated at a low velocity of 5 m/h. A post treatment of reverse osmosis after a pretreatment of GAC and anthracite biofilters showed a reduction in normalized flux decline (J/Jo) from 0.22 to 0.12 and 0.35 to 0.21 during the first 20 hours respectively. The RO flux for seawater declined at a faster rate and continued even after 3 days when no pretreatment was provided.

Based on the experiments, it was found that both media filtration (dual media) and biofiltration are appropriate pre-treatment before RO. In particular, Biofilter led to a consistent removal of organic matter over a long period of time.